CLEAN SUBSTITUTE SPECIFICATION

MODULAR INFRARED IRRADIATION APPARATUS AND ITS CORRESPONDING MONITORING DEVICES

FIELD OF THE INVENTION

The present invention refers to a modular infrared irradiation apparatus which employs combustion gas and its respective monitoring devices. Particularly, the apparatus of the present invention is directed to thermal transfer operations to provide quick and efficient thermal energy transfer at high rates for industrial drying operations in the paper making and cellulose industries. The irradiation apparatus comprises automation means for controlling the starting and all steps of the procedure, which are performed by such equipment and permit multiple industrial applications.

BACKGROUND OF THE INVENTION

Technicians of the art, particularly those skilled in the continuous fibrous products manufacturing processes, know that a drying step (or a set of drying steps distributed along the process) is a necessary step for drying coating or impregnating substances added to the product.

Known drying techniques employ heat transfer by direct contact between the heat receiver and the planar and/or cylindrical heat source or by means of hot air blowing.

The Infrared (IR) drying technique is the most preferred because the direct contact step for heat transfer is avoided. Thus, this embodiment is normally employed for complementary drying applications in the traditional drying steps of the art.

For each known different drying step, the desired result, e. g. , substrate features, and surface and physical properties, may differ. Therefore, in view of the above, a refined technique,

derived from known embodiments, which is complemented by an IR drying step is seen as the best result.

Recently, the use of an IR drying process has been seen as the best alternative because such technique is suited to several industrial applications and to provide solutions for old problems of the art.

The IR technique has particular features and such features make a difference when applied to known heat irradiation apparatus of the art. The IR generation techniques are basically distinguished in the temperature average and in the frequency range of the irradiating element.

In heat irradiation apparatus production, the selection of building materials determines the IR emission ability of such apparatus with some ranges of frequency, i.e., metallic irradiation elements generate long and medium waves. Ceramic irradiation elements at high temperatures generate short and medium waves. Generally, short waves have better penetration features in substrates in relation to long waves, and permit that a substrate be dried without direct contact and avoiding damage to the dried substrate surface.

The electromagnetic energy produced at IR frequency bands, if correctly set, will be absorbed by the substrate in such manner that the material will change, firstly in its initial state by absorbing heat and modifying its temperature. For volatile substances like water, the absorbed heat permits a change of physical state, from liquid to vapor, and thus the drying step occurs by evaporating all volatile mass contained in the substrate.

The amount of water to be evaporated from the substrate is a particular feature of the product and depends on the manufacturing route and the final application of such product. Therefore, the intensity of thermal energy in each case is to be particularly determined.

IR use as a final controller of remaining volatiles in the substrate, e. g., the substrate humidity, is an alternative that depends of the irradiation element. If the element is able (or not) to change the heat emission power, the process is able to dry the substrate at the desired level.

Several types of irradiation models as mentioned above are known in the art. Most of them comprise a metallic frame which encloses irradiation elements in metal housings, such elements are installed side by side transversally or alongside of the process direction. The irradiation elements are positioned near ~~to~~ the substrate path, and at least one plenum air and/or air/combustible gas mixture distributor is provided.

Irradiation elements are positioned at a minimal distance from the substrate path in order to obtain a maximum of heat transfer efficiency and avoid unnecessary substrate distortions, e.g, cause wet bands in the substrate due to the temperature differences of the housings in relation to the irradiation elements.

Most equipment known in the art has such minimal distance limited by the housing. If they are closely positioned, "heat shadows" are created and it causes wet bands in the substrate. A good housing positioning is necessary to avoid such shadows. On the other hand, the necessary positioning reduces the equipment radiation ability and creates an air/combustion gas stream which makes the substrate difficult to dry. Thus, to avoid this problem, additional heat equipment is provided in order to keep a good global efficiency.

Other problems related to combustion gas mixture quality may occur. The systems of the art generally employ a non-standard combustible gas mixture composition. Such differences can alter the burning stoichiometry at the irradiation elements. As a result, the flame can return to the inner part of the equipment at the plenum zone or at the gas injection tips and cause explosions and the process is interrupted for long term repairs.

Another problem of the art is the employment of several feeding heat recovery ducts. Ducts occupy a considerable space in the production plant and reduce a best employment of the plant space and make new equipment installation difficult.

Some recent techniques employ irradiation elements made of continuous refractory ceramic plates as a radiation emitter. Such plates are designed to cover the width of the process and are longitudinally positioned at one or more sections. Such an arrangement comprises a limitation when the process is to be fitted for other ends.

Such models presently satisfy IR irradiation quality and operation maintenance necessities, but some problems are still found:

- Framed housings provide cold zones (shadows) and a bad heat distribution, thus the irradiation element is to be positioned farther and the global efficiency is reduced;
- Power modulation is necessary in some cases; therefore IR emission bands are moved to large wave regions (Planck Law for Black Bodies). This change reduces the penetration feature of IR rays, because the way ~~of~~ energy is absorbed depends on the length of the wave emitted from the emission element, it causes temperature gradient differences in the substrate, the evaporation is not effected and the substrate surface is burned. Depending on the technique, wave modulation is not~~;~~ possible.
- Equipment found in the art is not suited to permit sample collection from an open chamber and the residual oxygen content after the combustion is not detected.
- Even if all safety steps have been taken, all equipment of the art is potentially dangerous and an explosion hazard is possible. Irradiation element manufacturers of the art consider this possibility hard to occur, thus the design of such irradiation elements does not involve safety care.

Industries of the art need safe and low maintenance equipment for reduce the interruption time to repairs.

SUMMARY OF THE INVENTION

According to the above and in view of the above mentioned problems, the present invention provides a modular IR irradiation apparatus which employs combustion gas and its respective integrating devices to automatically control the air/gas mixture, for sequencing the process starting, for interlocking the equipment and the corresponding process. Some modifications in the irradiation modules have been done in order to eliminate shadow zones and to enhance gas flowability; such improvements are achieved by means of a fibrous ceramic. The fibrous ceramic has flexible pores through which the air/gas mixture flows, and after the air/gas mixture emerges from an escape surface an ignition means is driven and a fire line is provided and kept stable over the ceramic escape surface which acts as the IR irradiation element at high frequency bands.

This preferred embodiment permits a safe operation, because the flexible fibrous ceramic does not resist ~~to~~ pressure, causing minimal intensity explosions and providing soft fragments when exploded. The modular design permits multiple arrangements fitted to any drying~~,~~ process and enhances the continuous irradiation element operation.

All the above objectives are achieved according to the following steps:

- Refractory flexible irradiation module comprising stopping means which is high temperature resistant and avoid shadow zones and side losses of heat at the burning zone in the ceramic surface;

- Employment of refractory flexible ceramic plates having flexible pores which permit air/gas modulation, the flexible pores define the path of the air/gas mixture through the ceramic plate. When the flow pressure of the mixture is reduced, part of the pore automatically closes and the combustible mixture is conducted to the surface where the hot fibers are placed. The fibers keep combustion active at the surface, multiplying IR heating effects. Ceramic plates of the art tend to "swallow" the flame causing an inner burning and reducing the efficiency of the process and/or loss of control of the flame and equipment explosion.

- Sensors and measuring means are provided for monitoring all steps: **Thermal sensor** - safety device applied in the lower face of each flexible fibrous ceramic module, more particularly fixed in the support screen of the ceramic plate and extending to a median line of such plate, for monitoring a possible heat flow inversion due to external factors which cause the "flame swallowing". For example, a heat reflection means positioned in front of the irradiation element in order to return IR energy back to the irradiation element and creating a resonance effect to store heat in the irradiation element and make the flow inversion. This device avoids misemployment problems by blocking the irradiation element. This provides an extended work life of the ceramic plate. **Oxygen measuring means** - Continuous measuring based on Zirconinum oxide. This device collects combustion gases over the burning surface in at least one module of refractory ceramic, for continuous analysis ends, permitting a flame optimization e and an after burning residual oxygen control. Such a sensor is connected to a LPC (Logical Program Controller) of the monitoring, interlocking and alarming system which is driven when the level of oxygen does not match the standard value. **Ultraviolet (UV) Flame detector** - It is applied in the external face of the metallic frame, more particularly, near ~~to~~ the combustible gas inlet, for flame detection, i.e., for combustion detection in the ceramic modules. The flexible

ceramic concentrates the burning in its surface, the IR generation occurs basically in the short waves range, including some residue at the beginning of the UV spectrum which is identified by the UV detector. The UV detector is assembled as a cathode anode discharge vessel, known in the art, inserted in a housing or specially designed device to support severe operation conditions. The housing has a cylindrical shape made of metallic material provided with a lower hole and channels for better air circulation. Refrigeration air flows from refrigeration ribs and also from the ceramic discharging tube of the receptacle body of the sensor, keeping the inner pressure positive and external particulate material entrance is avoided (the equipment can use two UV flame detectors); **Bed** - all flexible refractory ceramic modules and the first and the second plenum distribution means are positioned in the bed which is made of metallic plates having two handles and two mirrors and bottom caps and couterventing strips. Between the handles and the bottom caps is a safety system to permit an easy opening of the caps for maintenance or to avoid bed expansion in case of explosion. The locking system permits the effects of an explosion.

APPLICATIONS AND ADVANTAGES

Several advantages are achieved by means the present invention. The novel modular IR irradiation means and its electronic devices permits better control during operation and an enhanced global efficiency for thermal energy.

Other advantages are as follows :

- Flexible ceramic modules of the present invention permit uniform IR emission in all burning zones, avoiding shadow zones without irradiation;

- The absence of shadow zones permits the irradiation surface to be placed near to the substrate avoiding losses caused by air/gas streams and providing a collimation cavity for IR emission to avoid radiation scattering.

- Ceramic plates in the irradiation modules comprise other features of this invention, since they meet thermal-physical requirements and avoid energy dispersion over the limits of burning zone edges.

- LPC can be programmed to logoff some modules when others are still active and meet substrate width variation requirements.

- The fiber web has some anisotropic free grade related to a particular movement. When the gas passage is forced through the flexible ceramic, other pores are forced to open avoiding pore saturation, making the pores equivalent in relation to the conduction ability of the mixture. The average pore diameter is automatically adjusted to keep balance between the pores. This permits a gas volume, and power level modulation, and the discharge rate controlled and fitted to the minimum limit.

- The oxygen measuring means application makes possible residual smoke collection after burning for continuous monitoring of residual oxygen and can detect failure in combustible gas feeding. Other features of such means are that it is able to keep a high burning efficiency and keep the previous defined stoichiometry to obtain the desired temperature and IR band results.

- Two rectangular plenum employments as mechanical supports of the modules permit gas mixture feeding in the modules by means of modular valves or blocking valves, when modifications and/or improvements are necessary.

- The metallic frame building having inner pressure rate and overpressure alleviating means, meets the safety requirements for explosion proof equipment, providing a safe operation for workers and equipment.

DESCRIPTION OF THE DRAWINGS

The present invention is best defined, but not limited, according to the drawings as follows:

Figure 1 is a perspective view of the modular heat irradiation element provided with some irradiation modules in ready to use position and one module in exploded view;

Figure 2 is a cross sectional view of the IR irradiation element of the present invention;

Figure 3 is an exploded perspective view of ~~a~~ an irradiation module, illustrating all its components;

Figure 4 is a sectional view of an oversized detail of the stopping means in the ceramic plate ;

Figures 5 and 6, illustrate, respectively, side and sectional views of the irradiation module;

Figure 7 is a perspective view of part of the bed and primary and secondary plenum distribution ducts;

Figure 8 illustrates the entire bed with more details, in exploded perspective, showing the positioning of the oxygen measuring means and flame UV detectors;

Figure 9 is a cross sectional view of the bed, showing the mounting system with safety device for alleviating the explosion;

Figure illustrates an oxygen measuring means, in a more detailed perspective view;

Figure 11 illustrates the oxygen measuring means mounted on the IR modular irradiation element;

Figure 12 is an exploded perspective view of the UV sensor bulbs in the support housing; and

Figure 13 is sectional view of the UV flame detector of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the Figures, the present invention refers to a MODULAR INFRARED IRRADIATION APPARATUS AND ITS CORRESPONDING MONITORING DEVICES, the modular heat irradiation apparatus (1) is directed to a heat transfer operation involving elevated rates of heat continuously transferred to a receiving substrate, e.g., industrial drying process of fibrous products as paper or cellulose (L) (Figure 2).

According to the present invention and Figures 1 and 2, the modular heat irradiation apparatus basically comprises a metallic frame or bed (2) which is designed to receive a number of irradiation modules (7), according to process width and in such a manner to receive distribution and support ducts, primary plenum (3p), secondary plenum (3s) which possesses gas/air (G) mixture feeding outlets (3a) to the modules (7).

The employment of two plena having rectangular shape (3p and 3s) serve as mechanic supports of the modules (7) in order to position them in such a manner to permit the gas/air mixture (G) feeding in the modules (7) by means of a modulation/blocking valve (VL) coupled to the primary plenum (3p) or blocking free directly coupled to the secondary plenum (3s). The module presents a unique mixture (G) inlet (4) which can be aligned to the primary plenum (7v)

or secondary plenum (7d), depending on the final application which can be defined by turning the module 180° and by opening outlets or passageway (3a) of the primary plenum (3p).

Such procedure can be accomplished even after the original assembling is concluded when a modification is necessary or when power control is installed.

Plena (3p, 3s) are fed, firstly by the primary plenum (3p) employing at least one inlet or side duct (4), which is further used by the secondary plenum (3s) by means of an inner joint (JR) which is optional and restricting means (Figure 7).

The bed (2) is made of two mirror joining laterals (LI/LC) having lower laterals (LI) and axle type fixing inlets or supports (4) (Figure 1) which are fixed to the processes by means of locking bearings (M), permitting adjustment of the equipment angle at the moment of installation in relation to substrate flow direction (L).

Also, the bed has the upper side (LS) comprising lateral channels for alleviating thermal dilatation (AD) and resisting temperature variations between the upper edge and the lower edge and receiving refractory material (MR) to the irradiated IR, in order to define one irradiation cavity (CR), joined the frontal face, which is provided with irradiation modules (7). Such modules (7) are transversally positioned to the longitudinal axle of the bed (2) and arranged side by side in order to define a regular planar surface. The bed is further closed by metallic caps (6) which description will be provided below.

The mirror (EI) of the bed (2) (Figure 1) is provided with sealing air inlet duct (AS) to keep the inner cavity of the equipment pressurized and refrigerated; such air inlet duct (AS) has an independent feeding and is directed to avoid entrance and storing non-desired materials and gases in the cavity, protecting the frame against gas losses. The pressurized air is directed to UV system refrigeration and venturi system, both detailed in the present application.

Irradiating modules (7) can be made in variable dimensions and widths, and according to Figures 3, 4, 5 and 6, each one of the irradiation modules (7) is made of metallic material base receiver (8), containing a feeding hole (9), positioned and not centralized in relation to the surface of such base, for aligning with other plenum support (3p/3s) at the moment of mounting, just inversing the module according to the plenum. The mounting at the side of the plenum (3p or 3s) is achieved by employing a stopping ring (11) fitted to the feeding hole (9), which ring permits a good positioning of the module when fixation occurs over the distribution plena (3p, 3s) and each module (7) is fixed in the plena by restraining pins (P).

The base receiver (8) receives at its free edge, a screen (12) containing holes (12a) having suitable dimensions and shapes, in the lower face of the screen (12) are fixed at least two sets of sensors of thermal flow (14) interconnected by electronic circuit (13); such sensors extend over the screen to deep contact the penetration layer of the ceramic (15) where the sensors are fixed thereto. The sensors are interconnected to an electronic device (14a), which is connected to the LPC central, not shown.

At the upper face of the screen (12) is positioned a porous flexible refractory ceramic plate (15), in which median part, under the central line (Y) (Figure 6), the thermal flow sensors (14) are positioned. The housing depth is determined at moment of the mounting.

Each refractory flexible ceramic plate (15) (Figure 4) is made of sealing means (S) which is high temperature resistant and arranged in thin ceramic housings (16) and placed at the side faces of the ceramic plate (15) by means of a high temperature resistant elastomer (17) layer (Figure 4) which is able to penetrate between the parts (15,16) in order to produce and anchoring phenomena, adhering to said parts and avoiding lateral dispersions (D) of combustible gas in the

ceramic plate (15) through the screen holes (12a) by stopping them. This keeps the burning zone restricted to the face (D1) in the surface of the ceramic plate (15).

The block comprising the flexible refractory ceramic plate (15) and the thin ceramic housings (16) is fixed to the screen (12) by means of an elastomer layer (17) suited to high temperatures, complementing the sealing means of the irradiation modules (7) and producing a flexible joint which supports natural vibrations which occur during the operation of the equipment, and fit different materials possessing very thermal dilatation coefficients, i.e., the different ceramic materials and the metallic carcass.

One of this features of the refractory ceramic plate (15) is the flexible pores (see detail A in Figure 3), where the fiber positioning (F) is kept ready to move (V), due to forced passage of gas (G); this free movement feature permits a dynamic distribution of the gas flow through the pores (R) of the fibrous structure, thus making the pores open and/or closed when necessary, depending on the use condition and keeping the balance between them. The gas volume flowing through the ceramic plate (15) is able to be modulated and the emission power of the irradiation element is indirectly modulated by varying the combustible gas volume (G), but keeping active the discharge rate of the pores compatible to the combustion rate, therefore, the flame is stably positioned at the first layers (D1) of the flexible ceramic.

Another feature of the flexible ceramic (15) is that even under mechanical erosion the above mentioned properties are maintained, because the above described phenomena, which keeps the flame balance, occurs in the surroundings of the fire line, i.e., at the first 3 mm to 5 mm depth of the flexible refractory ceramic plate. Erosion or removal of part of such surface material does not modify the flame balance which always occurs at the surface (D1) of the ceramic plate independent of the surface shape.

Another property of the ceramic plate associated with the flexibility feature and not affected by erosion, as stated above, is the ability of the irradiation element to resist ~~to~~ dropping contamination, e. g. , ink drops in a continuous painting process of paper. The drop material at the irradiation surface can be easily removed by mechanical procedures of scratching or abrasion, avoiding other cleaning procedures and the system is quickly restored.

The bed (2) (Figures 1, 2 and 8) as previously stated, is made of lower side metallic plates (LI) having angular flaps (18a), closing mirrors, blind mirror (EC) and instrument mirrors (EI) having holes suited for the devices to be fixed therein, and bottom caps (6) having side flaps (6a) and closing flaps (22 and P1) ; such side plates(LI) are alternated with counterventing channels(21) while the bottom caps (6) have one flap (22) at one side fixed by engaging to one of the (LI) flaps (18), and at the other side, the flap is fixed by means of screws (P1), therefore is provided one safety divide between the lower side plates (LI) and the bottom cap (6). The particular geometry feature of the caps permits that the flaps (18, 22) to be easily unlocked, offering an escape area for gases, in the case of internal explosion, the cap (6) is fixed to the structure by means of the screws (P1) for permitting the removal of the cap for maintenance ends.

Modular heat irradiation apparatus (1) is equipped with automatic lighting devices and monitoring means, which are interconnected to the LPC, not shown, such devices comprise a trigger (CT) and sensors of thermal flow (14), oxygen measuring means (23), and the UV sensor (Figure 13), better detailed ahead.

Automatic lighting system comprises the assembling of some trigger electrodes (CT). The lighting is produced by ionizing the air by using a high tension source which discharges over

the bed (2). The triggers are mounted in a number which is enough to permit the lighting of the irradiation element, even when part of such triggers are disabled.

Thermal flow sensor (14), which position has been previously detailed, is responsible for monitoring heat flow inversion, since each sensor (14) monitors a maximum temperature differential between the median line (Y) of each ceramic plate (15) and the temperature of the feeding gas of the module, the verification occurs at the LPC for turn the equipment off when the differential is greater than the maximum permitted limit, this would indicate thermal flow inversion, i. e. , the flow is returning to the gas plenum and probably an explosion will occur. The thermal flow sensor is also used to indicate an erosion process in the ceramic plate and when the replacement of such plate is necessary.

The Oxygen measuring means (23) (Figures 10 and 11) employ, a sensor (26) based on Zirconium oxide, which is positioned in one device containing a temperature controlled chamber (26) (temperature control system not indicated), and such device is formed by five tubular bodies (27,28, 30,31 and 33) welded (29) one to the other, the set is fixed by a holder (34) positioned in the inner flap of the upper side (LS). An extension is fixed to the tubular body (28) forming a venturi type system, the tube (30) having the greatest diameter seals pressurized air inside the bed. When the sealed air passes between the tube (30) and the broader section of the tube portion (31) it is accelerated in order to effect vacuum inside the portion (31) and in the body (28), providing a vacuum chamber, while the collector tube (33) conducts the smokes collected in the inner part of the chamber (28). The collection tip (35) is coupled to the upper portion of the tube (33) and holes and concentrating flaps (37) are provided in the lower part (36) of such tip. The lighting system also employs tip (35) as ground contact to discharge the trigger.

The oxygen measuring means (23) is applied near ~~to~~ the burning zone (D1) in order to continuously analyze the combustion of the irradiation element, optimizing burning and controlling the amount of residual oxygen after the combustible burning. Such sensor is connected to the LPC of the monitoring system. Parameters of operation are adjusted in view of the desired application and the kind of combustible gas ~~is~~ used.

UV detector (24) (illustrated in Figure 1 and more detailed in Figures 12 and 13) can be double assembled, i. e. , two flame detectors (24) can be for each irradiation element (Figure 1). Each detector has a UV sensor bulb which is commercially available and its respective encapsulating system (39) installed inside the cooling system (40) extends to collimation cavity of IR emission (CR) by a ceramic bulb (47) restricting and protecting the sight of the bulb and the sight field against obstructing clouds of vapor from the process or against UV emissions from other external sources. UV sensors (24) are positioned at the external side of the instrument mirror (EI), more particularly fixed to the supports (44) which are fixed by tubes employed to conduct the pressurized sealing air inside the support tube from the irradiation element ~~(4)~~ to the cooling body (40).

Each set of UV detectors (24) additionally comprise a cooling body (40) having ribs (41) at its external face in order to provide cooling channels to keep the internal housing chamber (42) of the sensors (38,39) cool ; such protection comprises a lower hole (43) which is coupled to a metallic box type support (44) through which cooling air and connection wires of the electronic excitation and monitoring (called flame relay) are conducted.

The ceramic protector tube (47) is fixed to the cooling body (40) by the flange (45) which possesses inner tips as restraining means (46) of such tube (47).

A skilled person will see that the scope of the present invention is novel : irradiation modules, the monitoring performed by the sensors and measuring means via discrete electronic controls or LPC, the modular heat irradiator and its improved shape, a high efficiency of the heat transfer between the irradiating surface and the receiving substrate, the equipment designed for being easily adapted in any industrial process and all beneficial effects achieved by these means which permit remarked improvements in volatile removal from substrates, particularly wet removal from paper of cellulose drying processes, and the inventive concept which permits ~~a~~ long term use of the equipment of the present invention and reduced maintenance interruptions.

The above mentioned invention is detailed to offer the best understanding, but the same is not limited to the applications or particular details presently revealed.

Other embodiments and variations of the present scope are intended as belonging to the present invention.